# *Foreword*

In the Woolen Industry, as in many other industries, control and disposal of wastes is of major concern. There are two important reasons for increased attention to these problems: First, the greatest possible recovery, use, and reduction of wastes is necessary for most economical production in small as well as large plants. Second, protecting the Nation's limited water resources for maximum use is essential to our health and continued economic growth. Stream pollution control is mutually beneficial to industry, the individual citizen, and the Nation as a whole. Thus, wastes which cannot be eliminated must be disposed of in a manner which will not impair the usefulness of stream waters for other beneficial purposes.

This "Industrial Waste Guide to the Wool Processing Industry" is intended primarily to aid operators of woolen mills and commission processors to utilize, reduce, and otherwise suitably dispose of their wastes. The Guide was prepared by the Stream Pollution Abatement Committee of the American Association of Textile Chemists and Colorists, which is the technical association of the textile wet-processing industry. It was submitted for publication to the Public Health Service through the National Technical Task Committee on Industrial Wastes.

The National Technical Task Committee on Industrial Wastes is composed of representatives from the Nation's leading industries concerned with solving difficult industrial-waste problems. The objective of the organization is to perform technical tasks pertaining to industrial wastes in cooperation with the Public Health Service and all others concerned with improving the quality of our water resources. The preparation of this Guide was one of the tasks assumed by the Textile Industry in carrying out this objective.

This is the third of a series of Industrial Waste Guides prepared by the National Technical Task Committee in cooperation with the Public Health Service.

*an Industrial Waste Guide to the*

# Wool Processing Industry

*Prepared by the Stream Pollution Abatement Committee of the American Association of Textile Chemists and Colorists*

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service — Bureau of State Services

Division of Sanitary Engineering Services

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# Wool Processing Industry

## Introduction

The woolen-mill supervisor occupies a key position in reducing the polluting effects of his mill effluents. He can be particularly effective in the area of good housekeeping, which prevents wastes at the source and reduces manufacturing costs at the same time. This handbook is designed to assist him in exercising his responsibility for waste reduction and pollution control, and in recognizing those additional problems which require the services of the plant chemist and plant engineer.

With this primary purpose in mind, waste technologists and others in the Woolen Industry have attempted to design a concise, practical guide for wool-plant operating and design personnel. This booklet summarizes information made available over a period of time by many investigators. It emphasizes the appreciable reduction of waste which can be accomplished by waste-prevention measures within the processing plant. Practical methods of carrying out such waste-saving measures are discussed in some detail.

The section on waste treatment is not intended to be a comprehensive discussion of woolen-mill waste treatment. Sufficient information is included, however, to suggest possible solutions to stream-pollution problems which cannot be adequately corrected by waste-prevention procedures. Some performance data are included on various waste-treatment processes. This section may also serve to emphasize the value of waste-saving methods in reducing total waste-treatment costs.

## Description of Process

Wool processing consists of the following steps:

1. Opening and scouring.
2. Spinning.
3. Dyeing.
4. Finishing.

There are plants which perform each of these steps separately, often on a commission basis, and there are integrated mills, which carry out all of these functions from beginning to end. The processes involved in the steps above are described briefly in the following paragraphs:

### *Opening and Scouring*

Shorn wool is packed in bales and shipped to scouring plants for the removal of foreign matter. The bales are opened around a portable conveyor and fleeces are put onto the conveyor, blending the wools from many bales. The conveyor carries the wools to a series of pronged opening machines and dusters where the fibers are gently separated, and sand, grit, grass, etc., are beaten out of the mass. Some of these impurities remain stuck to the grease on the wool.

From the dusters the wool is dropped into a continuous scouring machine, consisting of a series of rectangular bowls through which the wool is propelled by reciprocating arms. Prongs on these arms dip into the scouring solution and move the wool from bowl to bowl through a series of squeeze rolls. The wool is dried and rebaled in preparation for the next process, or, if necessary, it is carbonized. Carbonizing is a process of removing vegetable matter such as straw, burs, and grass by steeping the wool for a short time in a dilute sulfuric acid solution followed by drying at a high temperature to dehydrate and char the vege-

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table matter. The stock is passed through a beater which brushes out the charred vegetable matter. The wool is then dipped into a neutralizing bath and redried.

***Spinning***

Dry wool is sprayed with an emulsion of oil and water as it passes over a conveyor belt. It is then carded and spun into yarn.

***Dyeing***

The process of applying color to wool involves a variety of steps. Wool may be dyed in any of three forms: loose fiber, yarn, or piece goods. The processes are nearly the same. The wool is put into a vat or dye kettle, commonly wood or stainless steel. The kettle is filled with water; salt, acid, and dye are dissolved, added to the kettle, and the material boiled for about an hour. The exhausted dye solution is run off, and the material is rinsed and dried. Several variations of this dyeing process are used depending upon the service to which the goods will be put. The above describes the most commonly used "acid dyeing" process. There are, in addition, neutral dyeing, which uses practically no acid; chrome dyeing in which the color is mordanted onto the fiber for best wash fastness; and metalized dyeing which uses a strong acid solution.

Dyehouses commonly carry out certain auxiliary processes connected with the coloring. Among these are scouring of yarn and piece goods to remove spinning oil, which would otherwise cause a resist to the adsorption of dye. To correct errors in dyeing and changes in orders, stripping of color from wool to prepare for redyeing another shade is often done. Stripping involves the use of a reducing agent in an alkaline or slightly acid solution, depending on the particular reducing agent.

***Weaving and Finishing***

Since weaving is a dry process, not producing liquid wastes, it is not of particular concern in the prevention of water pollution.

Finishing applies most particularly to piece goods. The first step in finishing is fulling, in which piece goods are soaked in a soap solution and put through a series of roller mills until they have become felted and shrunken to increase their body and density. The goods are then put through a washer to remove soap and emulsified spinning oil. They are then dried and ready for dyeing or cutting.

There are many integrated mills which, within one large building, carry out all of the processes described above.

# The Polluting Effects of Woolen Mill Wastes

***The Meaning of "Pollution"***

Water is said to be polluted when its character is changed, by addition of materials or in any other manner, in such a way that the usefulness of the water is reduced.

In their natural state, most bodies of surface water and flowing streams are relatively clear, colorless, and contain several parts per million of dissolved oxygen which is supplied by absorption from the air and to some extent by plant life in the water. The dissolved oxygen in the water is as necessary for the existence of fish and many other desirable kinds of life in the water as the oxygen in air is for the existence of man and animals on land. Clarity of the water permits the transmission of light which retards undesirable bacterial growth and generally contributes to a healthy and balanced population of aquatic organisms. Fresh waters in this kind of environment are usually suitable for most uses—as a source of municipal and industrial water supplies, for recreational bathing and fishing, irrigation, etc.

Pollution represents any undesirable departure from the condition described above. It can occur naturally as well as artificially. The most common form of natural pollution occurs when rains wash dirt from uncovered ground and heavy streamflows stir up the bottom. The stream is thus polluted by muddying, which may destroy animal and plant life on the bottom, reduce fish populations, and render the water less suitable for many beneficial uses. Land-use practices of man contribute greatly to this form of pollution. Another source of natural pollution is the leaching of excessive quantities of salts or harmful materials from the formations over and through which the water flows. The alkali waters of the Southwest are examples of this type of pollution.

Manmade pollution results chiefly from the discharge of wastes from cities and industries. Domestic wastes are relatively uniform in composition and in their effect on streams. Methods of treating municipal sewage are fairly standard. Therefore, wastes from the plant's sanitary facilities can usually be discharged to public sewers without special concern to the plant operator.

In contrast, industrial wastes vary widely in character and in their polluting effects; therefore, each type of waste is a special waste-treatment problem.

Most organic substances undergo a more or less gradual chemical or biological change which takes dissolved oxygen from the water. The extent of oxygen depletion depends on the rate of this oxygen demand in relation to the reaeration characteristics of the stream. If the dissolved oxygen is reduced below certain limits, desirable fish and aquatic life cannot exist. Complete removal of dissolved oxygen results in a septic stream which is characterized by obnoxious odors, floating solids, and a generally disagreeable appearance. Suspended organic solids may deposit on the bottom of quiet areas in the stream, concentrating the oxygen demand of these wastes in those areas. Waters containing considerable organic material are generally unsuitable for municipal and industrial water sources, recreational and some agricultural uses.

The introduction of disease organisms or harmful bacteria into the stream is another form of pollution which is particularly harmful to uses such as drinking-water sources, recreation and bathing. Sewage is the principal cause of this type of pollution.

Excessive concentration of soluble inorganic salts generally render water less suitable for industrial and municipal water sources. Concentrations of sodium and boron salts above certain limits cannot be tolerated in irrigation water. A serious disadvantage of this type of pollution is that soluble inorganic salts are not usually removed by natural stream purification processes; therefore they may affect use of the water far downstream from the point of entry. Acids and alkalies react to form salts and in addition have corrosive effects on boats and structures in contact with the water.

A number of substances are toxic to fish and aquatic life. Many of the metals which may be present as salts fall in this category. The acids, alkalies, and numerous members of other classes of compounds may have similar effects. Some substances are toxic to humans also, if present in sufficient concentration in water supplies.

The pollution may be in the form of the addition of tastes, odors, and color to the water. Phenol is an example of pollutant which results in serious taste problems in drinking water supplies. Color in itself is esthetically objectionable, particularly in drinking and recreational waters. Some industrial process waters must also be free of color.

Suspended inert matter may also have detrimental effects on the utility of the stream. It makes the water turbid, reduces light penetration and much of it eventually settles on the bottom. The turbidity increases the cost of treatment required for municipal and industrial uses. Deposits on the bottom may harm bottom-dwelling aquatic life, reduce the carrying capacity of the stream channel, and shorten the useful life of reservoirs. There are instances in which the deposition of industrial wastes has increased the dredging necessary to maintain ship channels.

Listed in table 1 are some of the principal polluting effects of certain types of materials frequently present in industrial wastes.

TABLE 1.—*Polluting effects of some industrial waste components*

| *Polluting agent* | *Effect* |
|---|---|
| 1. Acids, alkalies, and inorganic salts. | Toxic to fish and aquatic organisms. Deteriorate boats and structures in the water. Detrimental to municipal, industrial, and irrigation uses. |
| 2. Dyes | Add color which is esthetically objectionable in drinking and recreational waters. |
| 3. Inert matter, such as pigments, clay, coal dust, etc. | Adds turbidity, settles on stream bottom. Reduces desirable fish population. Increases municipal and industrial water treatment costs. Interferes with navigation and may reduce useful life of reservoirs. |
| 4. Organic matter, including organic oils, greases, and salts. | Depletes dissolved oxygen, eliminating desirable fish populations. May add tastes, odors, and turbidity detrimental to industrial and municipal water supplies. Forms floating scums esthetically objectionable and harmful to recreational uses such as bathing. |

Woolen-mill wastes, like many other industrial wastes, normally contain several of these kinds of polluting materials, and therefore may have a number of detrimental effects on the stream. For instance, wool scouring wastes can render a stream turbid and alkaline and remove all of the available oxygen. If this is al-

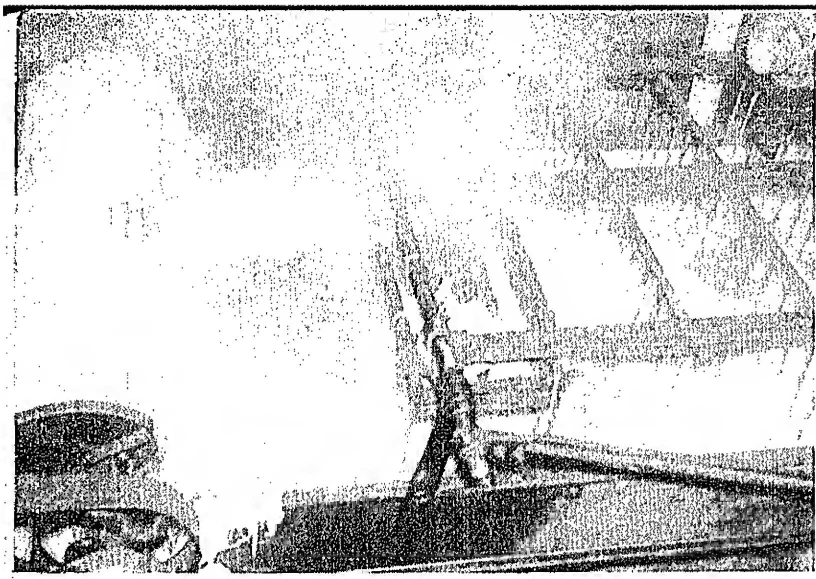


Figure 1.—Wool scouring uses 3 gallons of water per pound of wool and produces the most offensive of all textile wastes.

lowed to happen, fish are killed, and the stream gives off obnoxious odors formed by the septic decomposition of the emulsified greases and other organic constituents. Dye wastes together with the salt and acid in them create almost all of the above effects except turbidity.

### *Polluting Effects of Specific Woolen-Mill Wastes*

We shall now examine the polluting effects of individual woolen-mill waste solutions. The following table lists the polluting characteristics of the major wastes. The data were taken from a number of references and represent average values around which considerable variation can be expected from mill to mill. These differences arise from corresponding differences in the grease content of various wools, and differences between mills in the water-to-wool ratios in dyeing or scouring.

Table 2 gives the characteristics of the individual wastes. The stream usually receives a mixture the composition of which depends on the relative amounts of the individual types present. In one mill, for instance, the total output consists of 20 percent wool scouring waste, 30 percent dyeing waste, 30 percent yarn washing waste, and 20 percent from all other sources, including water softener backwash and sanitary facilities. A plant which is primarily a scouring and carbonizing plant will have a waste that differs greatly from that of a dyeing and finishing plant.

Many studies of woolen wastes have been undertaken. One of these, conducted at Lowell Technological Institute (ref. 46), evaluated the manner and extent to which wool scouring liquors contribute to stream pollution. Various methods of treatment were surveyed, and it was determined that control of the scouring process played an important part in the amount of pollutional materials discharged.

TABLE 2.—*Properties of woolen-mill waste solutions*

| Waste | Gallons waste per 1,000 lbs. clean wool | B. O. D. of waste P. P. M.[1] | Composition | pH | Color | Odor |
|---|---|---|---|---|---|---|
| Wool scouring | 8,000 | 6,000 to 10,000 (Refs. 29, 13, 37.) | 0.5 percent wool grease. 0.5 percent Suint salts, grit, burs. 0.1 percent alkali. | 10.2 | Brown | Foul. |
| Acid dyeing | 3,000 | 400 to 4,000 (Ref. 48.) | 0.1 percent mineral or organic acid. 0.2 percent salt. | 4.0 | Variable light to strong. | Slightly acid. |
| Carbonizing | 500 | 20 to 50 | 5 percent sulfuric acid | 1.0 | None | Acrid. |
| Piece or yarn washing. | 5,000 | 250 to 350 | 0.2 percent spinning oil. 0.1 percent alkali. 0.05 percent soap. | 9.5 | Light brown | Soapy. |

[1] B. O. D.=Biochemical Oxygen Demand, a term which signifies the amount of oxygen which will be taken out of the water in the decomposition and stabilization of the waste. The value given in the table is the number of parts by weight of oxygen used per million parts of waste in 5 days at a temperature of 20° C.

Another report by H. G. Baity (ref. 2) showed that textile wastes have three primary bad effects on the streams which receive them:

1. They are toxic to stream life.
2. They deplete the oxygen in the water.
3. They impair the stream's physical characteristics and properties.

This report reviews waste-treatment accomplishments in the State of North Carolina.

England has had a severe problem from wool scouring wastes since long before wool processing became a major industry in this country. Barker (ref. 3) has noted that the Yorkshire area scours out 34,000 tons of fat, 33,000 tons of dirt, and 11,000 tons of suint salts per year, most of which end up in the rivers. Toward the end of the last century, the putrefaction of these wool scouring wastes evolved so much hydrogen sulfide gas that it was possible for the air above the water to burn. The Yorkshire Rivers Board has conducted detailed studies (ref. 1) on the causes of pollution, covering nontechnical phases such as the use of rented manufacturing facilities, the contract processing of waste, the use of joint outlets by several mills, etc.

How badly the receiving body of water will be polluted also depends on the amount of water available for dilution. Wastes from the largest textile mill, if mixed in the ocean, would not affect the quality of such a large quantity of water. Unfortunately, most textile plants haven't an ocean nearby but are located on streams with limited flows. This creates the need for waste control.

A large river can assimiliate more wastes than a small one; wastes which cause no pollution problem in times of high stream flow may cause serious conditions during periods when the stream is low. The mill operator should know the average, high, and low flow rates of the stream into which the mill wastes discharge in order to determine how much must be done to prevent pollution under all conditions.

# Methods of Dealing with Woolen-Mill Wastes

When a woolen-mill operator is confronted with a waste problem, he should consider four steps:

1. *Waste saving:* Waste can be reduced at the source by carefully controlling the manufacturing process. A simple example is the use of the least amount of acid in dyeing that will satisfactorily do the job, in order to minimize the amount of acid that finally gets out into the waste.
2. *Byproduct recovery:* Many mills have contaminated streams with wastes which, on investigation, were found to contain salable byproducts. The most common example in the woolen industry is wool grease.
3. *Combined treatment with municipal sewage:* In communities that have adequate municipal sewage treatment facilities, it may be feasible to discharge the woolen-mill effluent into the municipal sewerage system. This approach frequently requires no capital outlay and can generally be paid for on a sewer rental basis.
4. *Treatment of residual waste:* After everything possible has been done along the lines of the first three steps above, the final recourse is to treat the remaining waste to the extent required by the receiving stream. A number of treatment methods are available.

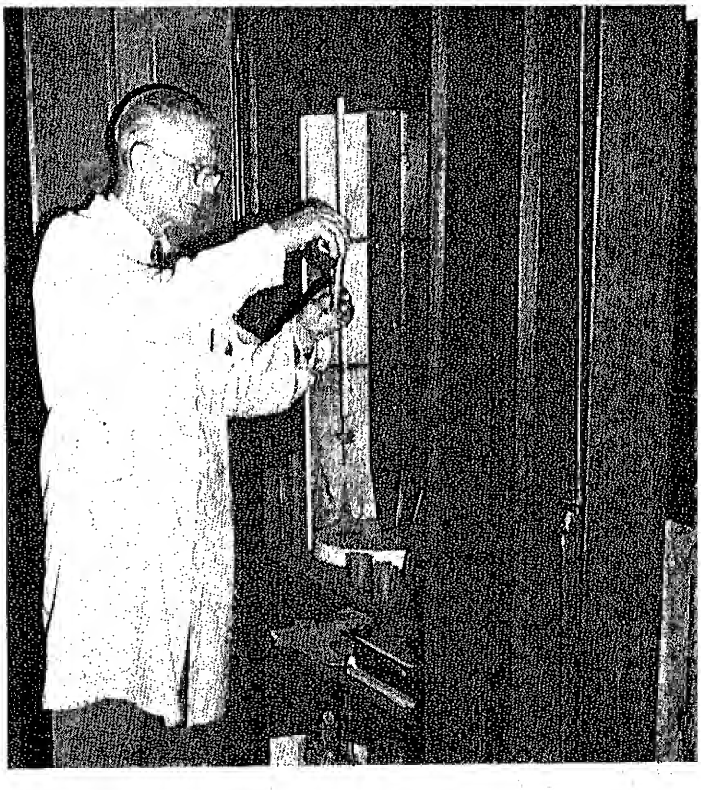


**Figure 2.—Titration control with metering of detergent and alkali to the wool washer reduces scouring cost, improves control and minimizes the alkalinity and variability of the scouring affluent.**

Each of these steps is discussed in the sections which follow.

With a planned program based on these four steps, almost any industrial waste can be satisfactorily disposed of without creating a stream-pollution problem; and among industrial wastes, woolen-mill wastes are not by any means the most difficult to handle. Now let us look at each of these four steps.

### *Waste Saving*

Logically, the first step in preventing stream pollution is to eliminate avoidable waste by careful control of production operations and to modify processes so that less harmful substances are in the plant effluent. Among industrial waste control people, much of this comes under the heading of good housekeeping economy, and almost invariably results in saving money. Some very fine investigations have been made of this approach in the textile industry.

1. Masselli and Burford (ref. 29) studied in detail the processing at two woolen mills and reached the following conclusions:

a. Many synthetic detergents have a much lower B. O. D. than soaps and the use of any of several detergents in place of soap could lower the oxygen demand load contributed by a woolen mill from 30 to 45 percent.

b. Mineral acids and ammonium sulfate have much lower B. O. D. than acetic acid. The substitution of the former for the latter in dyeing can reduce the B. O. D. of the plant effluent from 2 to 15 percent.

2. Snyder (ref. 55) has reported that the polluting effect of cotton slashing waste can be greatly reduced by using certain synthetic compounds like carboxy methyl cellulose as a partial or total replacement for starch.

3. Stafford and Northup (ref. 56) made comparative B. O. D. tests on about 175 textile chemicals and dyes. From this list, many suggestions can be taken along the lines of materials changes that can improve the characteristics of a woolen mill effluent.

The above are examples of material substitution. Equally fruitful is the field of material economy without necessarily changing the materials used. For instance, one mill which scoured as much as 400,000 pounds of wool per week changed its method of alkali control from conductivity measurements to titration and, by the more accurate metering of alkali into the washers, cut its soda-ash consumption from 10–12 pounds per hundred pounds of wool down to 4. Spaced over the period of a year this resulted in a saving of several thousand dollars and cut the alkali in the effluent almost two-thirds. The same has been shown to be true in acid dyeing; pH control in the dyehouse can be used to minimize the amount of acid put into the dye kettles, thus keeping to a minimum the amount of acid in the effluent.

R. H. Souther (ref. 57) has shown that the amount of reducing agent added in vat dyeing is usually in excess of what is actually required and that careful control can produce perfect results with greater economy of material. Since reducing agents have a tremendous oxygen consumption, this can be a very important point for mills which use a large quantity of vat dyes. In this connection, the Marhen process offers a good tool for controlling reducing agent through the measurement of redox potential.

### *Byproduct Recovery*

Whether an industrial waste is put into a municipal sewer system or treated at the plant and put into surface waters, the recovery of usable or salable materials from the waste lessens the degree of treatment necessary and generally reduces the cost of manufacturing operations. Byproduct recovery is economically justified when the value of the byproducts plus the reduced treatment costs exceed the cost of recovery.

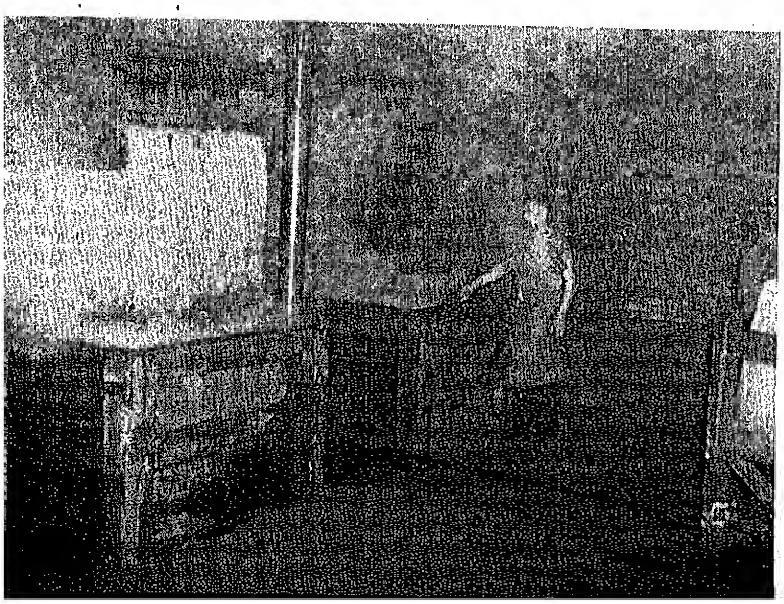


Figure 3.—The acidity and unexhausted color in dyebath effluent can be kept to a minimum by pH control.

In the case of woolen mills, there are presently few :ems which could possibly be recovered. These are 'ool fibers, wool grease from scouring operations, and ertilizer material from scouring operations. Re-search now going on may result in cheaper ways of ecovering other materials now considered too costly ) recover, and may find markets for other components f the waste which today are considered valueless.

The separation of wool fiber from waste is a rela-vely simple matter. Vibrating screens of a readily vailable standard design are in use for this purpose. uch vibrating screens are common chemical engineer-ig equipment. Another technique involving a filter rum is described in a German publication (ref. 4). Vool fiber disintegrates slowly and therefore has a ery extended period during which it will absorb xygen slowly from water. It has a more acute disad-antage of clogging pipes and sewage-treating equip-ient if the waste is put into a municipal sewer system. he recovery of short fiber is a distinct economic ad-antage since short fiber can be added to wool mixes i certain percentages.

There is a large body of information and experience n the recovery of wool grease from wool scouring olutions, and there are several techniques for recover-ig the grease, all of which work successfully. Wool couring wastes are the strongest polluting materials i the whole textile industry and the major factor to be onsidered in dealing with a waste problem at an itegrated woolen mill.

In addition to reducing the required residual waste eatment, the chief incentive for recovering grease is s salability, which has permitted profitable recovery i the last 7 or 8 years. Prior to this period, however, e wool-grease market had been noted for wide fluc-ation in price and there is relatively little confidence 'en today in the steadiness of price for the recovered ool grease. The Department of Agriculture is con-ducting research (ref. 36) designed to broaden the usage of wool grease, lanolin, and the components thereof. Another Department of Agriculture labora-tory project (ref. 25) involves a solvent scouring sys-tem in which not only the grease but the suint salts can be recovered. A report on this project has been made by its head, Dr. Harold Lundgren. In this case, a com-pletely new system of scouring is involved. A market must be developed for recovered suint salts in order to justify the process economically.

Details on the standard methods for grease recovery are available from many sources (refs. 5, 7, 13, 14, 18, 20, 22, 38, 39, 49, 50). These standard methods are based on two principles:

1. Continuously circulating the scouring solution through centrifugal extractors to remove amounts of wool grease in excess of a certain threshold concen-tration. The extracted scouring solution is returned to the scouring machines for buildup of grease con-centration and cycled again through the extractors.
2. The entire scouring solution is treated in a batch process of chemical precipitation such as by acid cracking or the addition of calcium salts to separate out the grease. The separated crude grease is then put through a filter press to remove solids, and is dried.

The relative amount of grease compared to the other polluting materials such as suint salts, dung, urine, dirt, grit, and burs in the scouring waste depends on the type of wool being processed. The grease will ac-count for about 80 percent of the oxygen required (Biochemical Oxygen Demand) by waste from the scouring of high grease content clothing wool. Sixty percent of this grease can be removed by centrifugal extractors. This will reduce the oxygen demand by 48 percent, or approximately one-half.

The centrifugal extraction process removes a smaller proportion of the grease from low grease content waste.

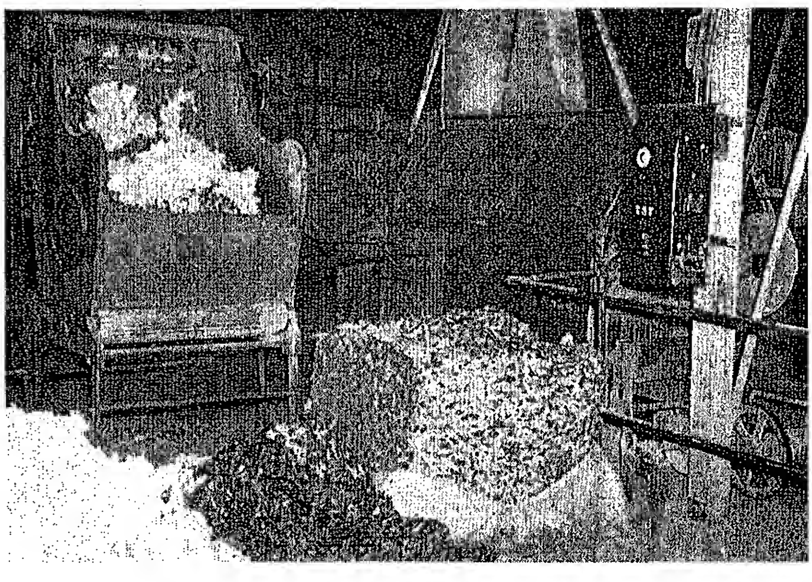


**Figure 4.—Efficient dusting before scouring reduces the waste load imposed on the wool scouring solutions.**

It is therefore a much less effective pollution reduction measure in plants processing low grease content wools.

Grease represents about one-half the oxygen demand in wastes from scouring low grease content carpet wools. The acid cracking process will remove practically all of this grease, which in turn reduces the oxygen demand of such scouring wastes by one-half.

The process for grease recovery requires a considerable capital investment, not less than $35,000; but if any volume of greasy wool is processed, the installation can be amortized in less than 5 years.

After the grease is recovered, there are two remaining components: the filter press cake which contains considerable organic matter, dirt, and grit; and the water phase of the scouring solution. The press cake can easily be dried by spreading out on the ground, and makes a good fertilizer. The water effluent is still not satisfactory for putting into a stream of high water quality and must be treated in any of several ways discussed later.

Two systems for solvent scouring have been tried with a view toward eliminating the stream pollution problem by reducing the amount of aqueous treatment given to wool in its lengthy processing through a woolen mill. Neither process is in use today. The first and oldest is a batch process for degreasing wool in a kier by circulating naphtha solvents through it. The naphtha with grease dissolved in it (ref. 55) was then filtered and the solvent evaporated and recovered. The second process was described by Oberholtzer (ref. 32) and consisted of a continuous scouring with trichlorethylene. The processes fell into disuse because of the following disadvantages:

1. The sale value of the recovered grease from a solvent process is not as great as from an aqueous scouring, since it is darker in color and contains foreign matter which is difficult to remove.

2. Inevitable solvent losses add a cost factor to the process which renders it noncompetitive to aqueous scouring.

3. In spite of the solvent scouring, there remained in the wool other foreign matter such as listed above which had to be scoured out in an aqueous medium after the solvent degreasing. This immediately returned the stream pollution problem, although not as severe as if the degreasing had not been done.

### *Combined Treatment With Municipal Sewage*

After setting up good housekeeping practices and any possible byproduct recovery so as to minimize waste at the source, the next possibility for mills suitably situated is to consider putting the plant effluent into the city or town sewerage system. This procedure usually involves the least capital investment. However, it must first be determined whether the nature of the waste will interfere with the sewage treatment and whether local arrangements can be made to dispose of the waste in this manner.

Several studies have been made to determine the effects of textile-mill wastes on sewer systems. It has been concluded that if certain conditions are satisfied, woolen-mill waste can be added to sewer systems. The factors which must be considered are:

1. Is the volume of mill wastes large or small in relation to the amount of sewage?

2. What are construction materials in the sewer lines, and will the mill wastes be harmful to the sewer lines or the joints between sections of sewer pipes?

3. How is the sewage treated, and will the addition of mill wastes overload or upset the operation of the municipal treatment plant?

4. If some treatment is needed to make the plant effluent suitable for discharge to municipal sewers, is such pretreatment feasible?

5. Assuming all these conditions to be favorable, what would be the cost for utilizing city sewer systems to dispose of woolen-mill wastes?

The following paragraphs review the findings of some studies that were made in an attempt to answer the questions above:

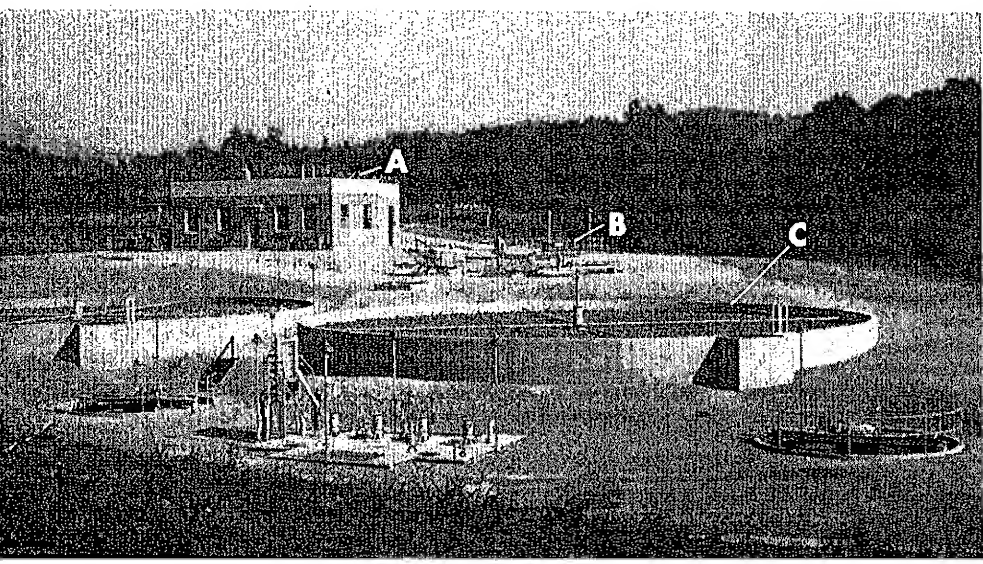



**Figure 5.—Representative waste treatment system showing, (A) chemical feed house, (B) clarifier, (C) trickling filter. Chlorination of the wastes is sometimes substituted for trickling filter treatment.**

The oldest reference (ref. 45) describes a study 28 of a small German town, population 7,000, e they successfully combined with the sewage amounts of waste from woolen mills which ed raw stock, dyed, spun, and finished woolen In this case, the sewage treatment processes ılation on long shallow sand beds, Imhoff tank, e drying beds) were a type for small cities only he quality of the final effluent would not be ade- for all purposes.

Rudolfs reported in 1937 (ref. 35) on labora- nd pilot plant studies of the effect of a number de wastes on high (70° C.) and low (20° C.) rature sewage sludge digestion processes. The s of the tests with woolen-mill wastes generally ted—

The addition of 10 percent by volume of wool ing waste to digesting sewage sludge had rela- little effect, but the addition of 20 percent led digestion.

The addition of 10 percent dye wastes reduced roduction up to 35 percent.

After a short period of continuous addition of astes the bacteria of the digestion process be- adapted to the wastes to the extent that diges- of the above concentrations proceeded satisfac-

Geyer (ref. 16) reports that in his opinion the nethod of industrial-waste disposal is combina- vith municipal sewage. He describes methods emical precipitation, filtration, and biological cation. This work included wool scouring and astes.

In Los Angeles (ref. 34) wool scouring wastes combined with sewage, but the sulfide content scouring waste caused odor nuisances and the tion of the hydrogen sulfide damaged concrete joints in the sewers. The problem was over- by reusing the rinse water in the scouring solution and treating the rest of the waste with ferrous sulfate. In this way, sodium sulfide was recovered, the sale value of which exceeded the cost for its recovery.

5. One other reference gives an excellent summary of the whole situation. A report from the Textile Foundation (ref. 42) discusses the pros and cons of putting textile-mill wastes into domestic sewer systems. The general conclusion is that it can be done providing certain principles are observed. These principles are—

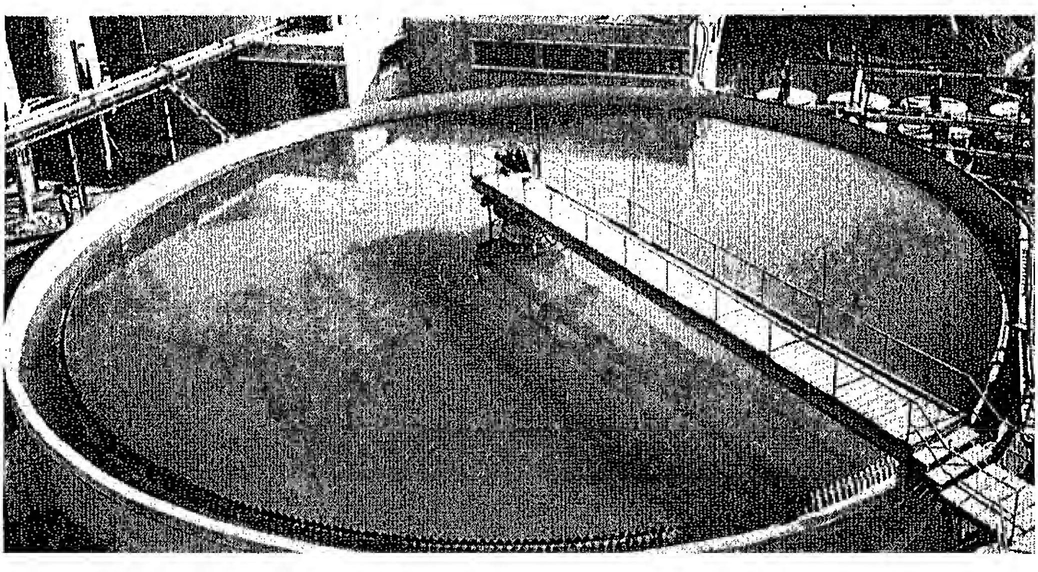
a. That the waste be made consistent in its character.

b. That the rate of feeding the industrial waste into the sewer system should be controlled to maintain a relatively constant ratio of waste to sewage.

The case of one large plant which used this procedure can be cited. The woolen mill scoured and dyed 300,000 pounds per week and put the waste into the sewer system of a community of about 80,000 people. It was found that with usual dumping of the equipment at the end of the day, large amounts of highly concentrated wastes would reach the sewage disposal plant and exceed the capacity of its chlorinating equipment. The problem was solved by the construction at the woolen plant of a large concrete pit, capable of handling all of the plant effluent for 1 day. In this pit the dye wastes and scouring wastes partially neutralized each other, and a great deal of the suspended matter settled to the bottom. A sluice was opened after the pit was filled so as to drain the pit slowly and uniformly into the sewer system over a 12-hour period, and the city sewage treatment was not adversely affected.

An excellent survey has been written by G. J. Schroepfer (ref. 58) in which he describes the various techniques for determining fair sewage service charges for industrial wastes. There are a number of methods by which an industrial corporation can pay the addi-

**.—Enlarged view of a er. After dosing with lating chemicals the is fed into a clarifier as this where the co- ed suspended mate- ttles. Sludge pumps er the settled materi- m the bottom of the er to sand drain beds ying.**



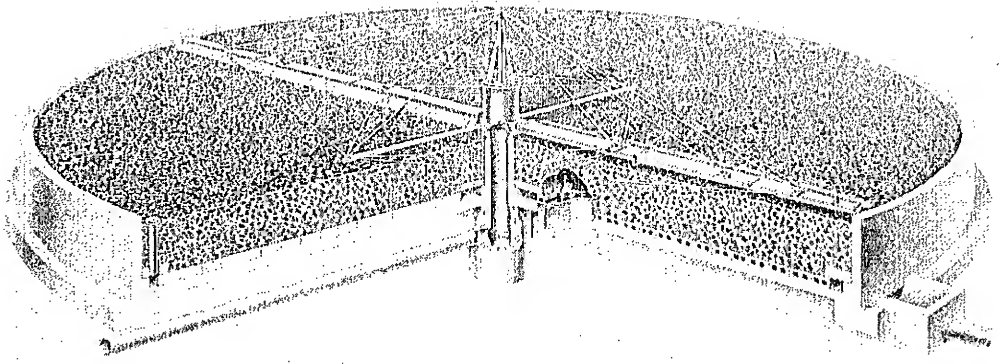


**Figure 7.—Detail of trickling filter construction. The aerobic bacteria living in the slime coating on the stones "digests" the organic matter remaining in the wastes coming from the clarifier.**

tional cost incurred by a city in handling their wastes in combination with sewage. Naturally, the additional measures to be taken to handle these wastes are dependent upon the nature and volume of the waste in relation to the equipment, daily sewage volume, and the nature of the treatment at the municipal sewage plant. Hazen (ref. 51) has also summarized the problems concerned with evaluating industrial wastes for the determination of sewer service charges.

### *Treatment of Residual Wastes*

This section describes the techniques that may be used for dealing with the residual effluent after all of the avenues that we have discussed above are explored. If this effluent is put into the municipal sewer system, nothing of course need be done. If, on the other hand, it is put into surface waters, some further treatment may be necessary. The nature and extent of this treatment will depend upon stream conditions and the uses to which the water will be put. Requirements established by State and local governing authorities are not the same in all areas and must be determined for each case.

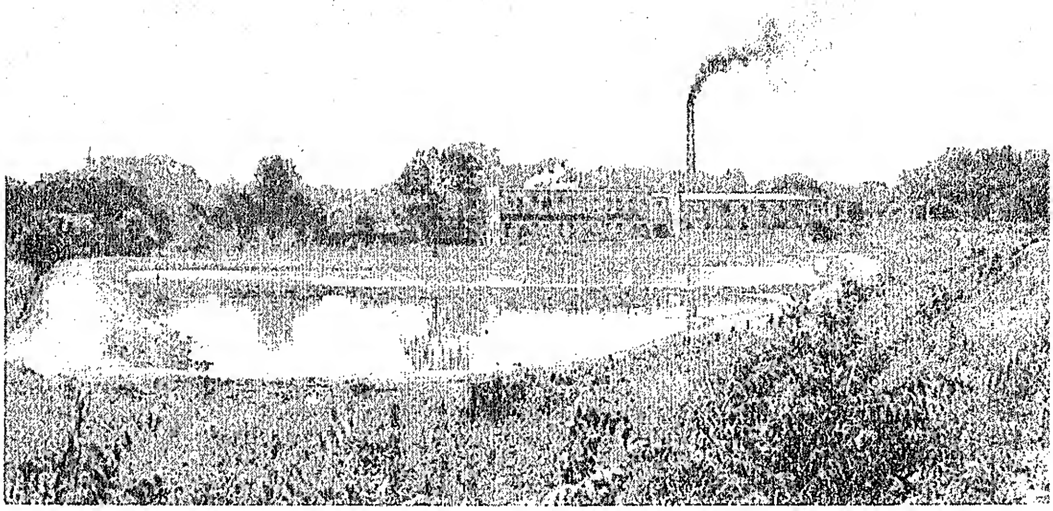
There are two references which summarize the laws in existence on water quality standards and water pollution abatement (refs. 52 and 54). Since many pollution abatement laws are of recent origin, the development of this type of legislation is to some extent experimental. Equally important to the words of the laws, therefore, are the interpretations given by the administering authorities. For this reason, it is vitally important in arranging for the disposition of an industrial effluent that the plant management be in contact with the agency administering the local laws that
n waste disposal.

len-mill wastes can be treated in a variety of ways so as to reduce turbidity, dissolved solids, acidity or alkalinity, oxygen depleting components, color, and bacterial content. The prior sections have discussed all of the steps that may be taken to recover useful material and to eliminate waste at the source. It is therefore the aim of the processes discussed here to achieve their purpose at the lowest possible cost, since these treatments are a net expense from which no return can be obtained. Fortunately, many of the treatments used employ very low cost chemicals.

It is a general premise that, where a mill produces more than one kind of waste, it is easiest to combine the various kinds of wastes and treat the combination as one. This reduces the number of treating units and usually results in handling a more uniform raw material. An integrated woolen mill will have as its major waste components the dyehouse effluent and the wool scouring effluent. As noted in a previous section, these wastes, if combined, partially neutralize one another. We will first consider what can be done if this practice is followed. We will then observe briefly how treatment differs in the case of mills which have only dyehouse effluent or only scouring effluent. Practices for the treatment of industrial wastes in general, which include textile wastes, are discussed in references 11, 21, 40, and 47. Droszdorf (ref. 11) surveyed the situation as early as 1923 and noted that woolen-mill wastes can be purified by simple chemical means such as coagulation with lime and ferrous sulfate. He concluded that biological means such as digesting systems and trickling filters offered the only method for complete purification.

Kuni and Platonova (ref. 21) studied chlorination as a method for purifying textile-mill wastes and noted that this precipitates much of the suspended and dissolved organic matter.

ƨure 8.—A lagoon is a cheaper substitute for the clarifier and trickling filter, but requires several acres of ground to retain wastes long enough for unassisted sedimentation and absorption of oxygen from the air.



The Connecticut State Water Commission summar- :d industrial waste research in 1948 (ref. 40) and termined costs for treating woolen-mill wastes with .m, iron sulfate, and chlorine. They noted that, as an erage, the treatment of woolen-mill effluents can be ne for 15 to 25 cents per thousand gallons.

Weston (ref. 47) described the characteristics of )olen-mill wastes in 1939 and enumerated the prin- )als for systematic treatment:

a. Equalization of flow.

b. Wool-grease recovery.

c. Chemical precipitation.

d. Drying the sludge which results from the precipitation.

e. Biological treatment of the clear liquor resulting from the chemical precipitation.

A number of other references (9, 10, 12, 17, 33) :al solely with textile wastes. Coburn (ref. 9) de- ribes a process for treating woolen-mill wastes in iich the various departmental effluents are composited sedimentation tanks, where sulfuric acid and alum e added to adjust to a pH of 6. This process precipi- tes out most of the solids which are then run off to idge drying beds and sand filters. A clear, almost lorless, effluent is obtained.

Eldridge (ref. 12) reported in 1942 that 83 percent moval of suspended solids and 72 percent removal of O. D. was accomplished by dosing a woolen-mill aste with 1 pound of lime and 3 pounds of ferric :loride per thousand gallons of waste. The character- :ics of the sludge and effluent are described.

Coburn and Oberholtzer (refs. 10 and 33) describe e system used at a carpet mill, similar to those de- ribed above. In this case, however, the effluent is it into small artificial lakes to permit a longer sedimentation period and absorption of oxygen from the air. The use of lagoons presupposes the availability of adequate land area, usually several acres for the average-size mill.

Goldthorpe (ref. 17) reviewed in 1946 a description of textile-waste disposition, which describes biological treatment, sludge treatment, and pressure filters.

McCarthy reported in 1950 (ref. 26) that woolen-mill wastes can be treated on trickling filters if pH is suitably adjusted. He noted that wool dye wastes are stronger than domestic sewage, and wool scouring wastes still stronger in their pollution effects.

Since wool scouring wastes are the most concentrated in the textile industry, considerable effort has been given to the disposition of this effluent alone (refs. 6, 8, 27, 28). Campanella (ref. 6) worked out a process for precipitating wool scouring wastes with calcium hypochlorite and adapted this to a continuous process. He notes that the results in terms of solids and B. O. D. removal are excellent.

Coburn (ref. 8) compared three methods for the treatment of wool scouring wastes; acid-cracking, calcium hypochlorite and calcium chloride with carbon dioxide. He found the chemical cost for the first to be cheapest and the second most expensive, and all gave a solids removal better than 85 percent and a B. O. D. removal better than 42 percent. He nevertheless found that the residual B. O. D. after treatment is higher than domestic sewage and, to be reduced, requires treatment through trickling filters.

McCarthy (refs. 27 and 28) studied the application of calcium chloride and carbon dioxide for the precipitation of scouring waste and obtained very similar results.

If dyehouse wastes alone are involved, the treatment must be different. The waste is acidic, contains very little suspended matter, and may be highly colored. In some cases, chlorination removes the color. A method more recently developed is the filtration of the waste through a bed of activated carbon. The carbon absorbs the color from the solution and can be regenerated and used over and over again. Fassina (ref. 15) recorded a forerunner of this treatment in 1937. He suggested neutralizing the acid in the dye waste with lime and then passing the solution through a porous material such as acid-treated wool to adsorb colored impurities. He determined that this purifies the waste to the degree that it is no longer injurious to fish life.

Thornton and Moore (ref. 43) reported in 1951 that Fuller's earth and activated bauxite are good adsorbents for dyestuffs from waste water.

Thatcher (ref. 44) described an automatic method for acid neutralization, whereby a lime slurry was fed into a continuous stream of acid waste, controlled by an automatic pH control unit.

Zack (ref. 48) showed that lime and ferrous sulfate coagulation remove 70 percent of the B. O. D. in dye waste. If this waste is then lagooned, the B. O. D. removed is better than 92 percent.

Sterling (ref. 53) notes that, to reduce the B. O. D. of acid dye wastes, the wastes can be treated by trickling filters.

# Summary and Conclusion

Controlling stream pollution has become an urgent necessity in the United States today. Our demands for usable water for public water supplies, industrial uses, and other beneficial purposes are now so great that we must reuse the same water many times as it flows from city to city. Pollution can prevent or add greatly to the cost of many water uses. For this reason, the wool-processing industry, like other industries, is giving greatly increased attention to reducing the polluting effects of its wastes.

This Guide summarizes the sources of pollution in the wool-processing industry, the polluting effects of woolen-mill wastes, and information on the methods of dealing with the waste problems of the industry. Four separate operations of the industry produce liquid wastes: opening and scouring, spinning, dyeing, and finishing. Significant polluting characteristics of these individual wastes include oxygen demand, suspended solids, acidity, alkalinity, color, and grease.

The polluting effect of the wastes may be reduced by substituting detergents for soap, mineral acids for acetic, synthetic compounds for starch, and similar changes. Limiting the amounts of acids, bases, and reducing agents to the actual requirements for the process also will reduce waste loads. Wool fibers, wool grease, and fertilizer material all may be recovered from the wastes. The wastes may be treated in combination with domestic sewage, or they may be treated by (1) coagulation and precipitation with chemicals, (2) chlorination, (3) biological processes, and (4) adsorption.

The information contained in this Guide can help the mill supervisor carry out his increasing responsibility to reduce the polluting effect of the mill wastes. Much can be accomplished through good housekeeping procedures which also reduce operating costs. The plant chemist and engineer can be most helpful in developing further measures.

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